The James Webb Space Telescope Mission

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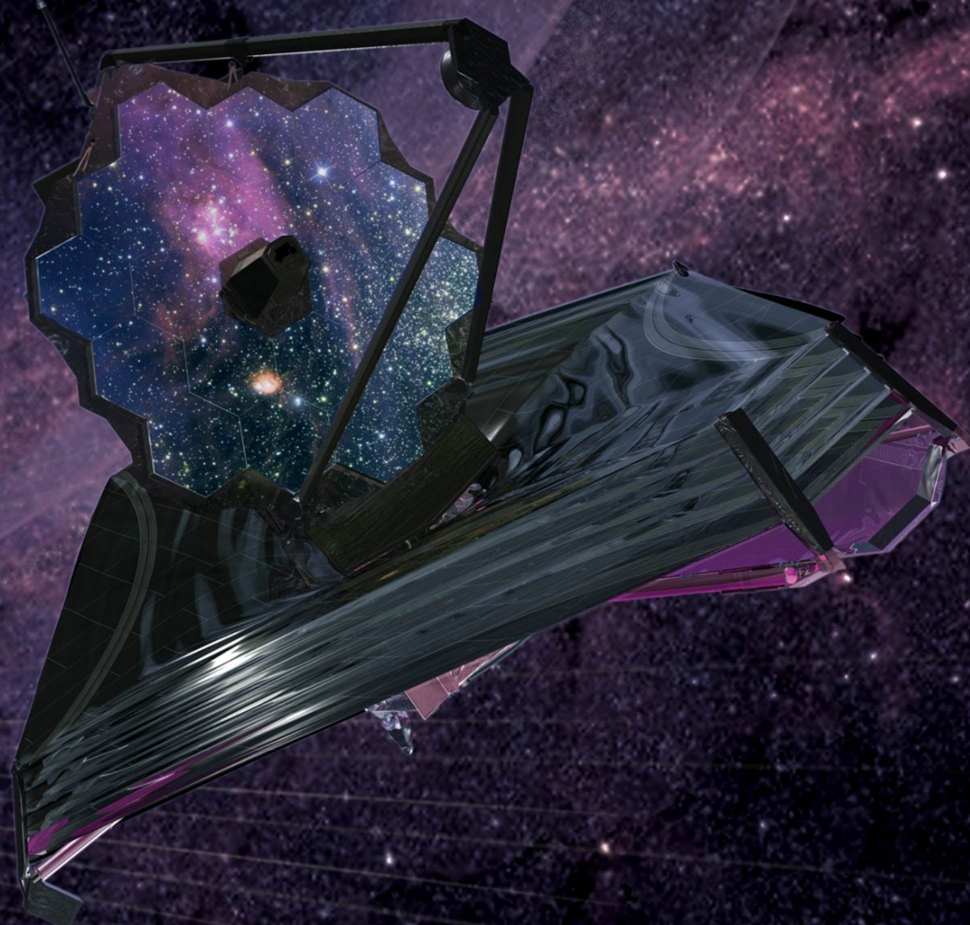
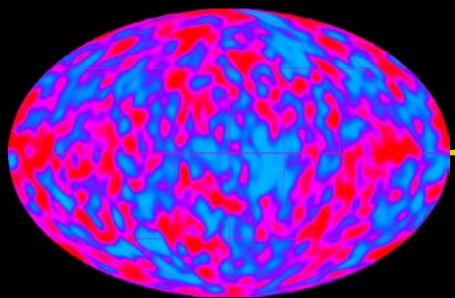
@NASAWebb

#JWST

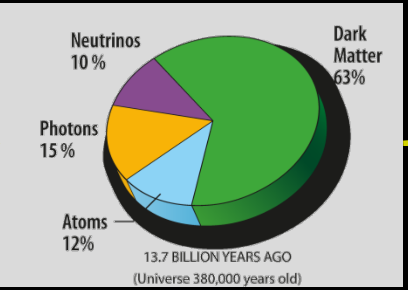


How did the universe evolve to produce the Earth – our world?

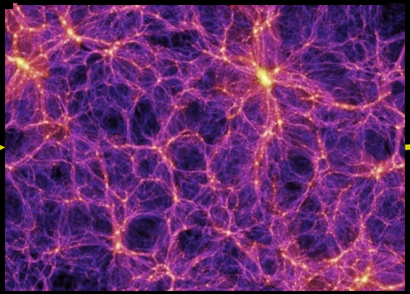
Oldest Light



Composition Then



Cosmic Web (simulation)

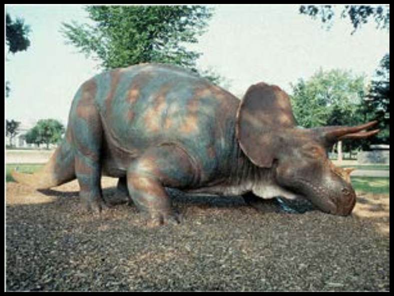


Irregular Galaxy Shapes

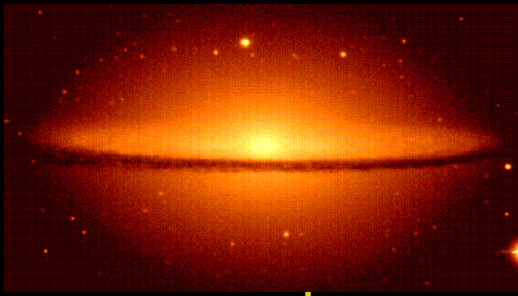
Planets With Liquid Water

DNA

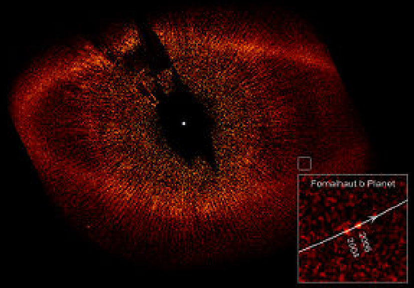
Life



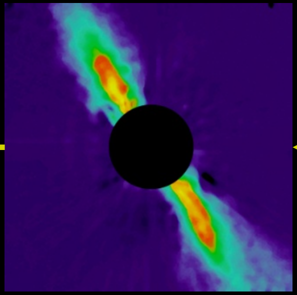
Symmetric Galaxy Shapes



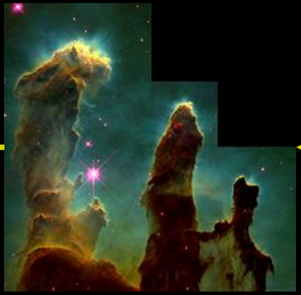
Extra-Solar Planets



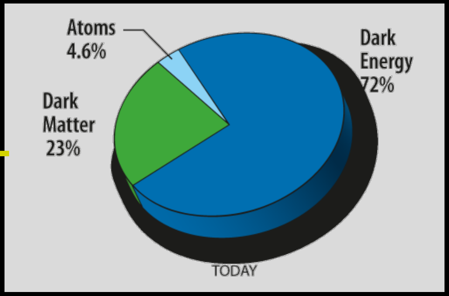
Stellar Debris Disks



Star Birth



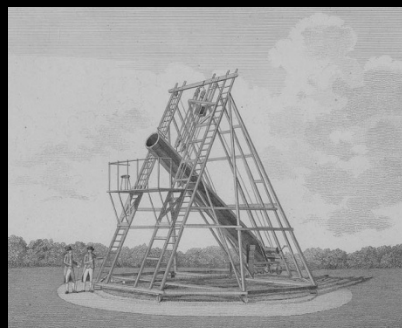
Composition Now



Humanity's quest to understand its origins is as old as recorded history.

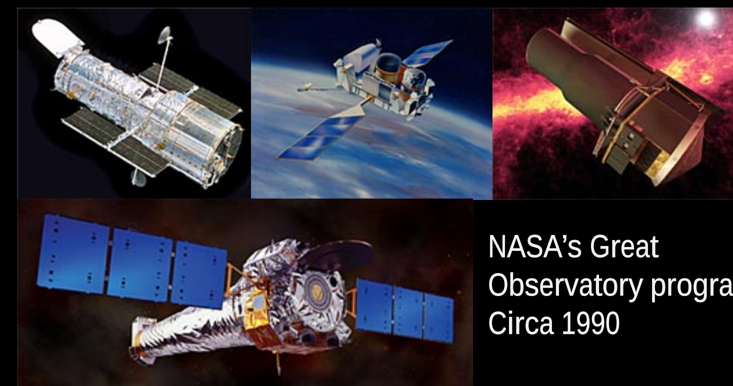
New tools for discovery are providing insights and questions at a rate that is unprecedented in human history

Astrolabe
Circa 1090 A.D.



Reflecting Telescope Circa 1800

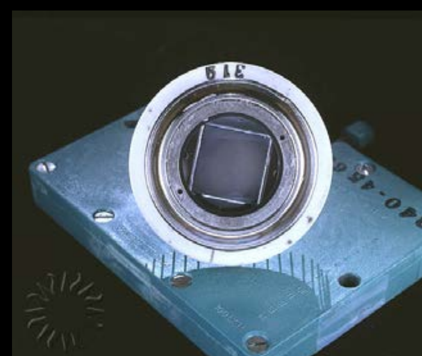
Spectroscopy Circa 1950



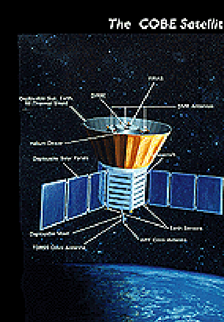
NASA's Great Observatory program
Circa 1990

Armillary Sphere
Circa 1500

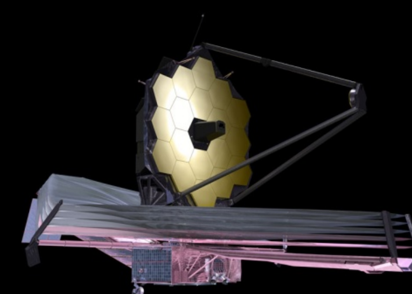
Photographic film replaces eye
Circa 1930



Electronic detectors replace film
Circa 1980

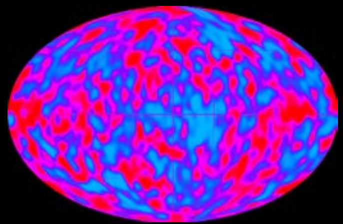


First light
Circa 1990



James Webb Space Telescope
To be launched 2018

Space telescopes are astronomer's most powerful tools for exploring the fossil record of the universe



The oldest light

The most distant galaxies yet seen

X-rays to infrared

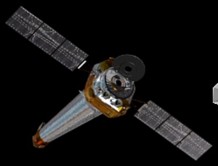
Birth & evolution of galaxies, stars, planets

The visible to infrared universe in HD

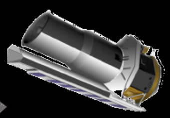
COBE 1989

WMAP 2001

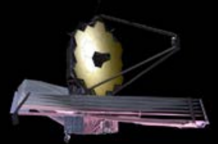
HST 1990



Chandra 1999

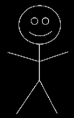


Spitzer 2003

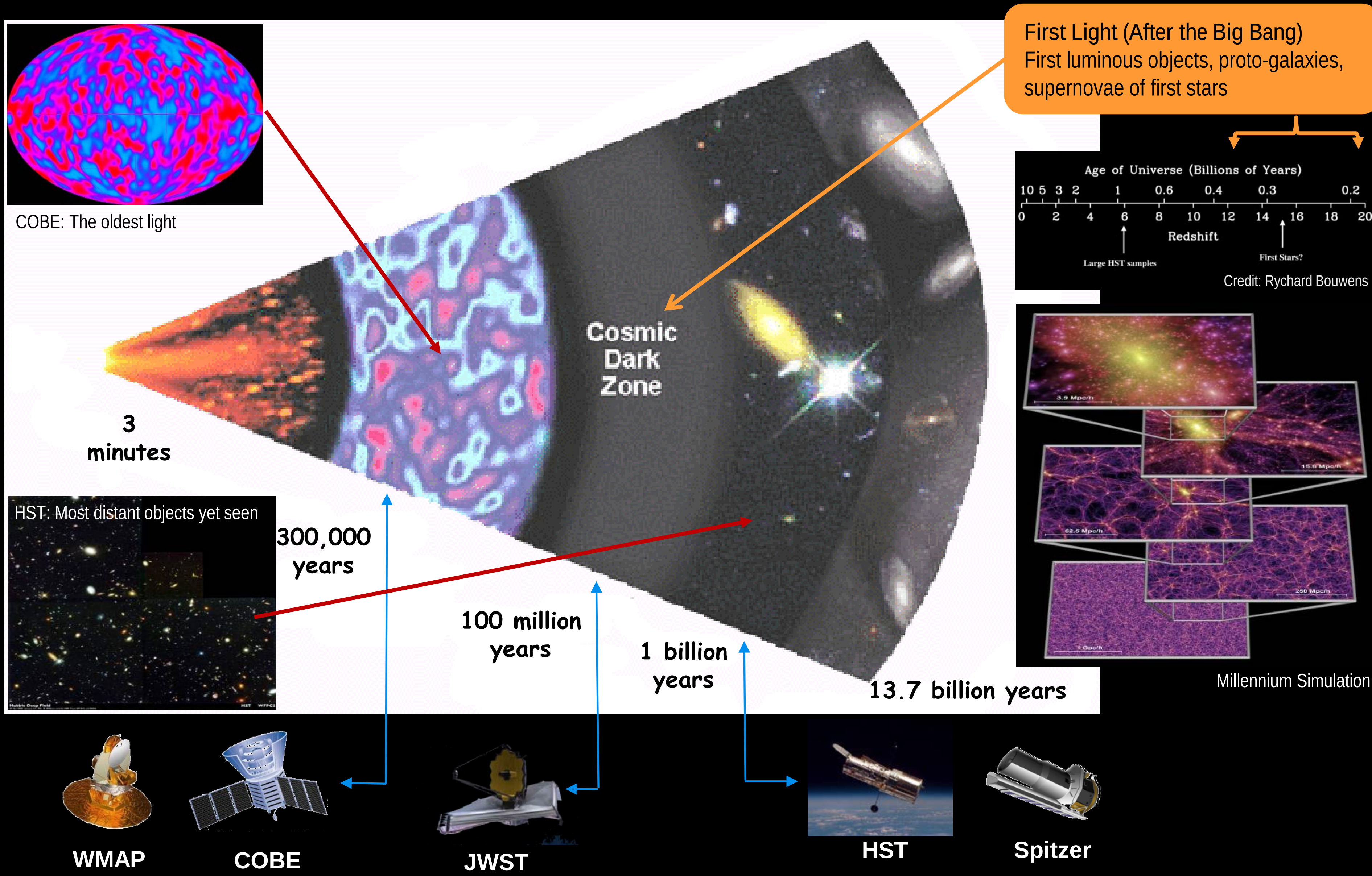


JWST 2018

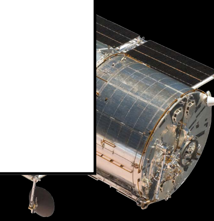
Traveling back in time is the stuff of science fiction, but looking back in time is science fact.

	People	Earth	Distance to Sun	Distance to Closest Star	Distance to Canter of our Galaxy	Big Bang
						?
	1 m	7000 km	150,000,000 km	270,000 AU		
Light travel time	0.000 000 003 s	0.02 s	500 s	4 years	25,000 years	14,000,000,000 years

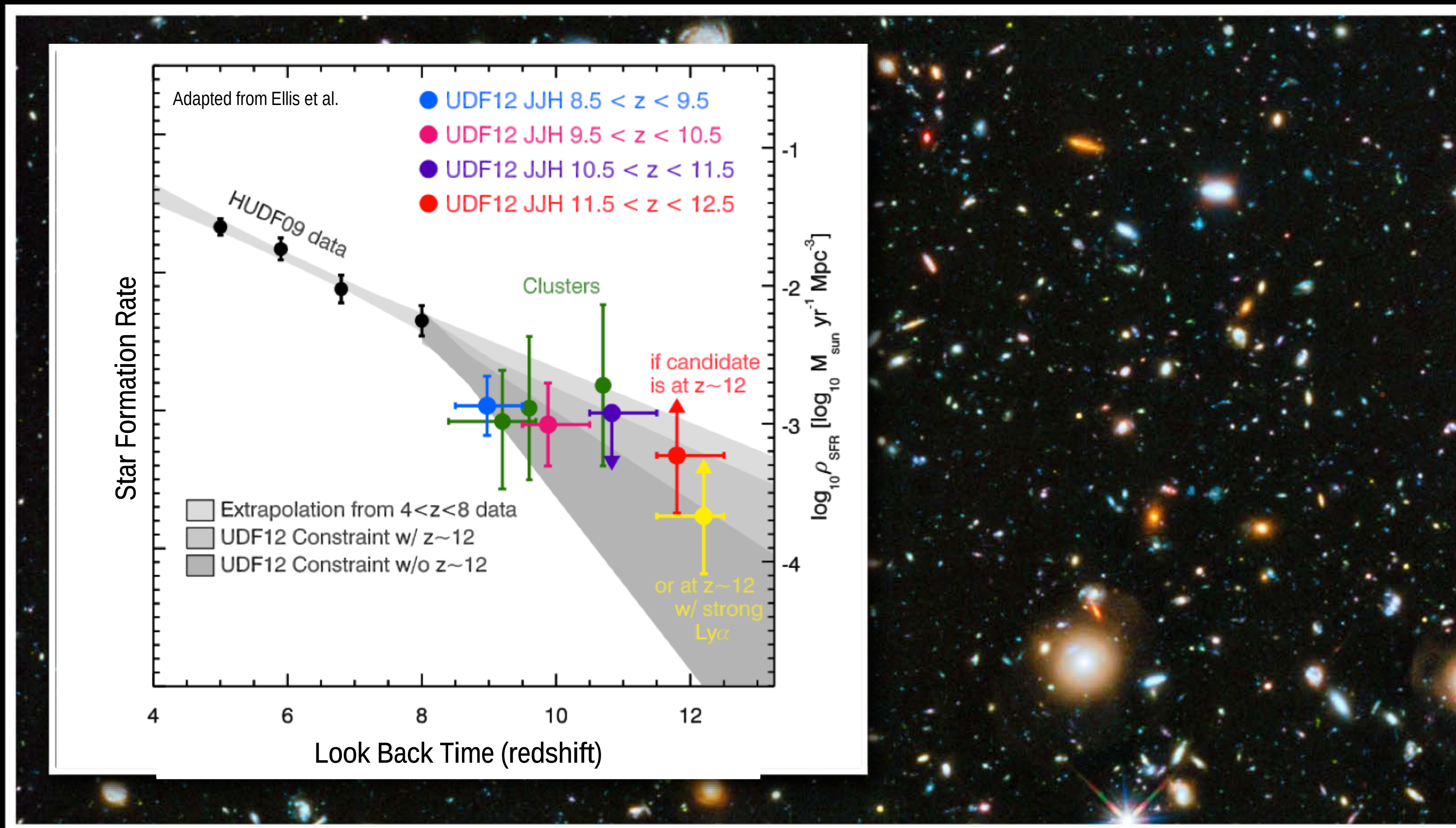
JWST is designed to look back in time to see the first galaxies

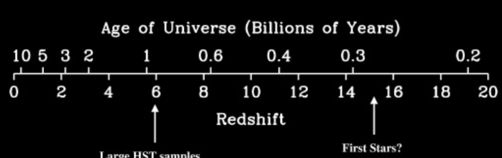


The universe is 13.7 billion years old. Hubble can look back in time to observe an epoch during which the universe was approximately 1 billion years old, and has seen some galaxies at even earlier epochs.



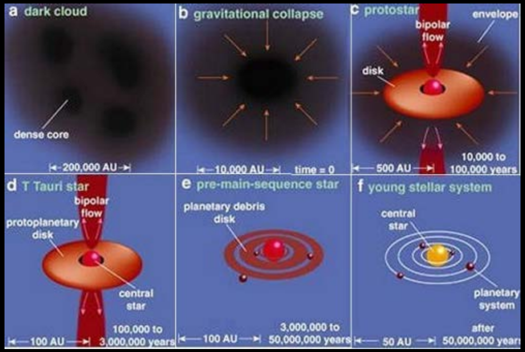
But, Hubble cannot look far enough back in time to see the first galaxies

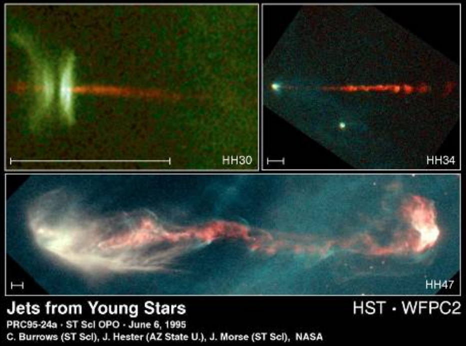




Light from primeval galaxies is emitted in the ultraviolet. As it travels to us through expanding space, its wavelength is stretched into the infrared spectrum

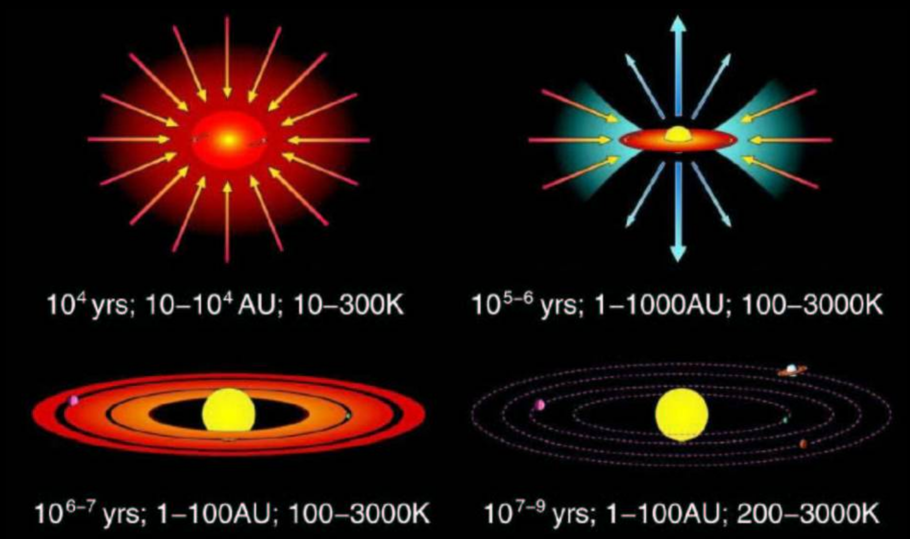
JWST will see into the birthplaces of stars to reveal how they form





Protostar

Circumstellar disk

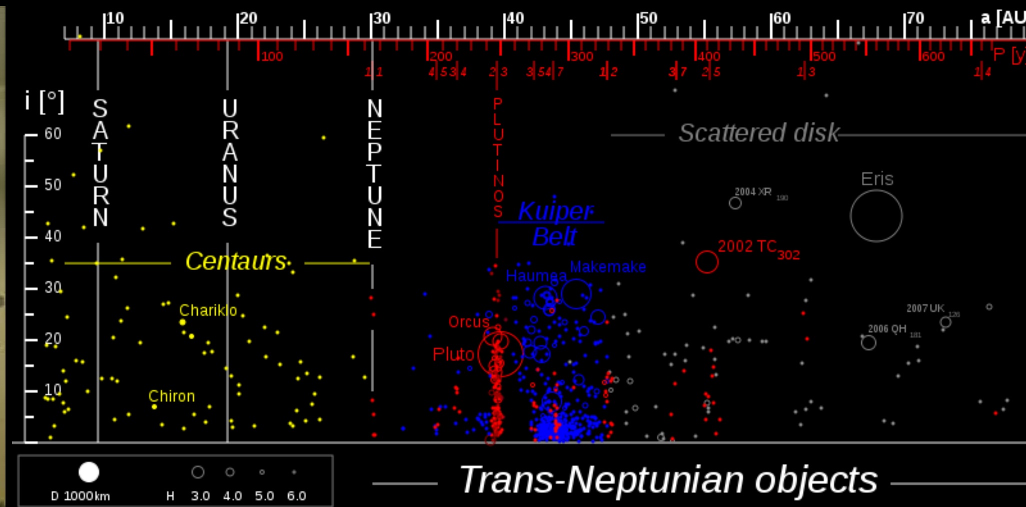


Planetesimals

Mature planetary system

The Eagle Nebula as seen in the near-infrared

JWST will observe how planetary systems form and evolve

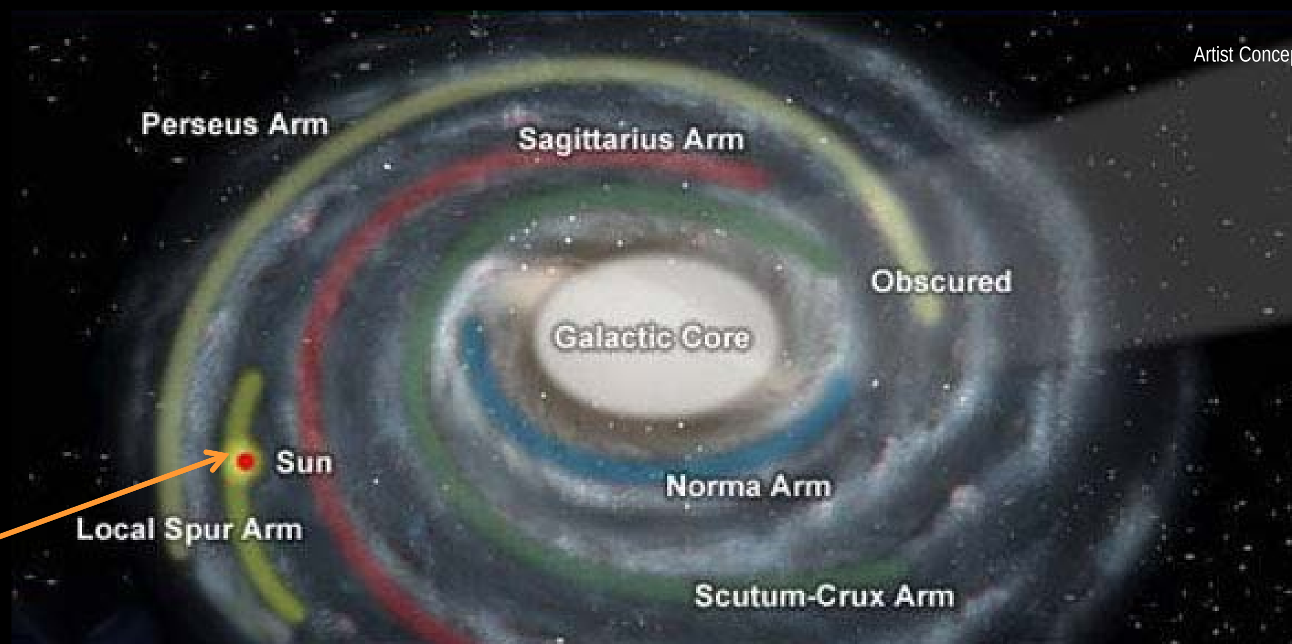


First Light (After the Big Bang)
First luminous objects, proto-galaxies, supernovae, black holes

Assembly of Galaxies
Merging of proto-galaxies, effects of black holes, history of star formation

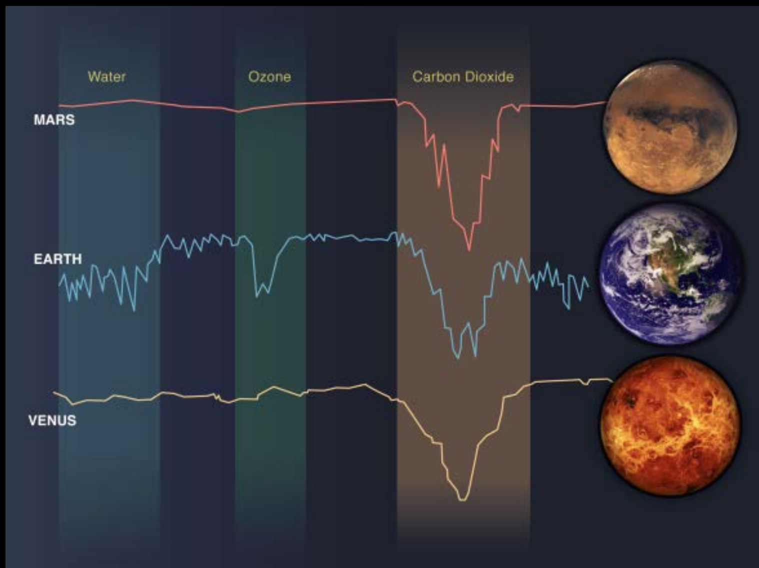
Birth of Stars and Planetary Systems
How stars form and chemical elements are produced

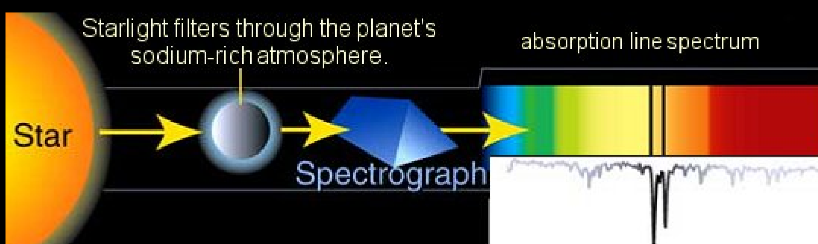
Planetary Systems & Origins of Life
Formation of planets



JWST will revolutionize understanding of exoplanet atmospheres

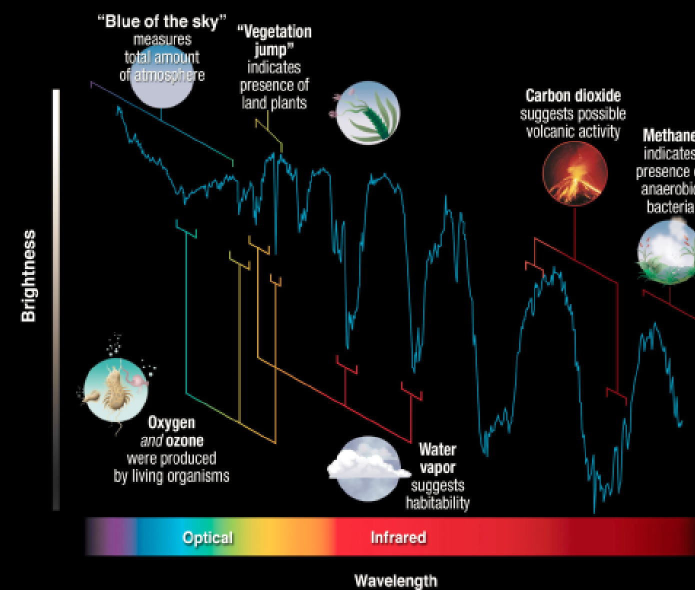
Composition is revealed by spectroscopy

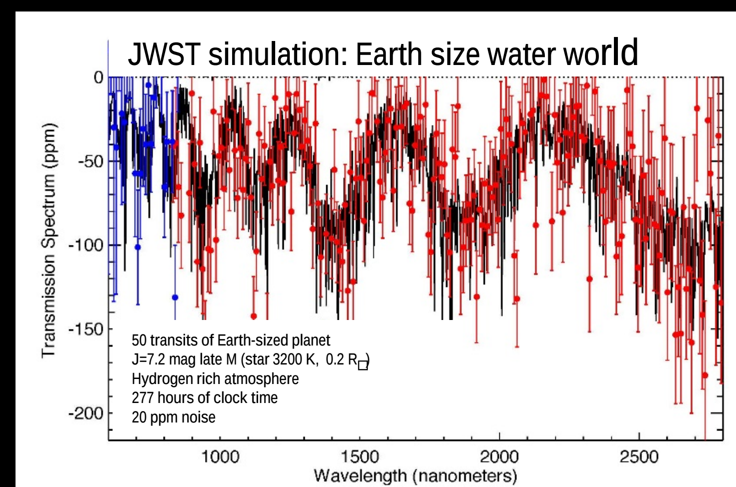




There are tens of billions of habitable worlds in our galaxy. JWST can detect liquid water on an exoplanet that is a few times the size of the Earth.

So is the presence of life!



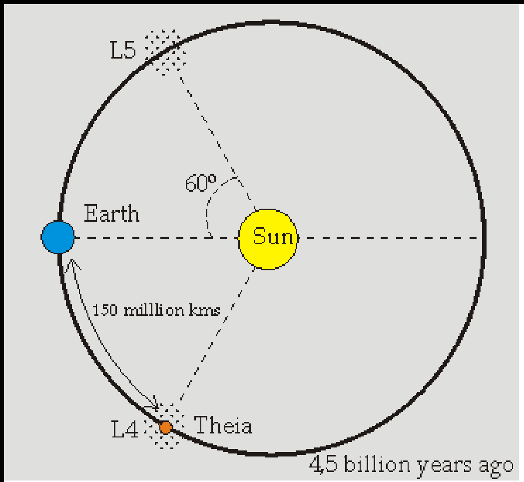


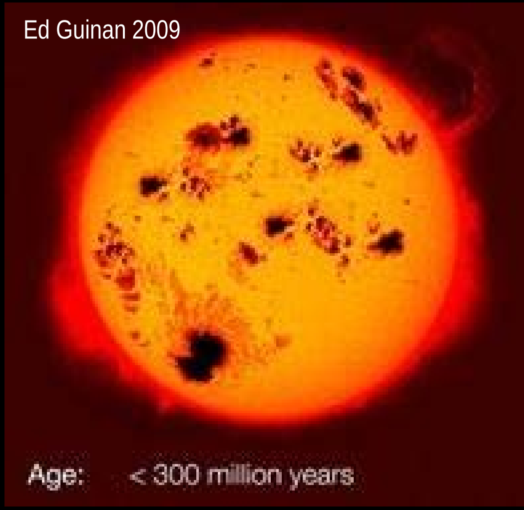
The JWST will study our solar system to learn how it and others evolve after their planets are formed

A possible history of the Earth:

- Sun and first solid bodies in Solar System 4.567 billion years ago
- Mars-sized body "Theia" hits Earth, melting everything, dispersing volatiles like C and H; debris forms Moon, 90 MY AF (after formation)
- Cool early Earth, possibly with water
- Jupiter, Saturn orbits switch (twice?), clear debris from solar system, cause "late heavy bombardment", "Hadean" geologic period, many craters, new water and carbon delivery to Earth, 400 - 700 MY AF
- Life forms shortly after (~ 3.8 BY ago); all life uses same genetic code!
- Young Sun very active, gets steadily brighter with time, warming Earth
- 300 MY from now – Plate tectonics produce super continent
- 1 BY from now – Sun 10% brighter; Earth too hot for us
- 8 BY from now – Sun becomes red giant and engulfs Earth

Hartman & Davis 1975

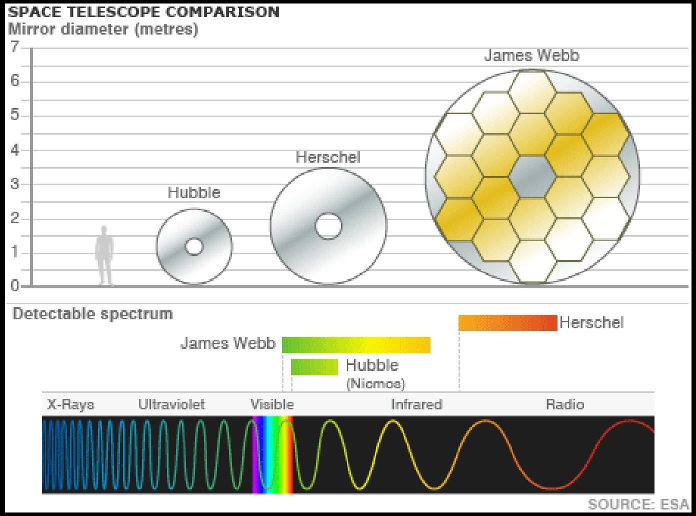


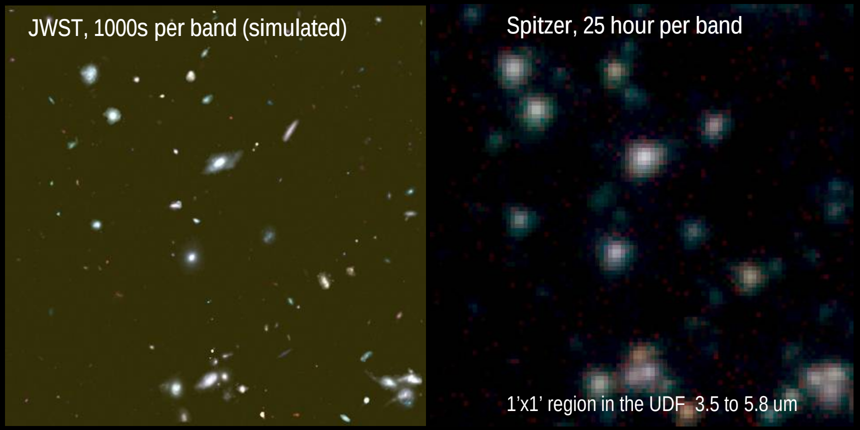


JWST requires the largest cryogenic telescope ever constructed

To achieve its science objectives, the JWST mission requires:

- 7X the light gathering capability of the Hubble Space Telescope
- Hubble-like angular resolution in the near-infrared
- Observing capability spanning the optical to mid-infrared spectrum





JWST will provide the first high definition view of the infrared universe

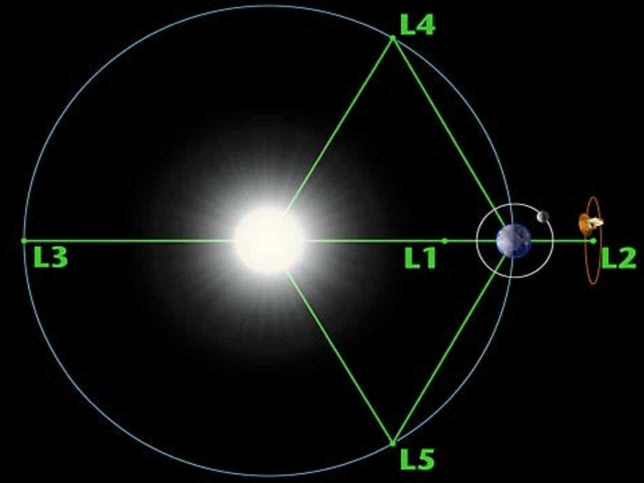
To meet these requirements, the JWST team had to solve two key problems:

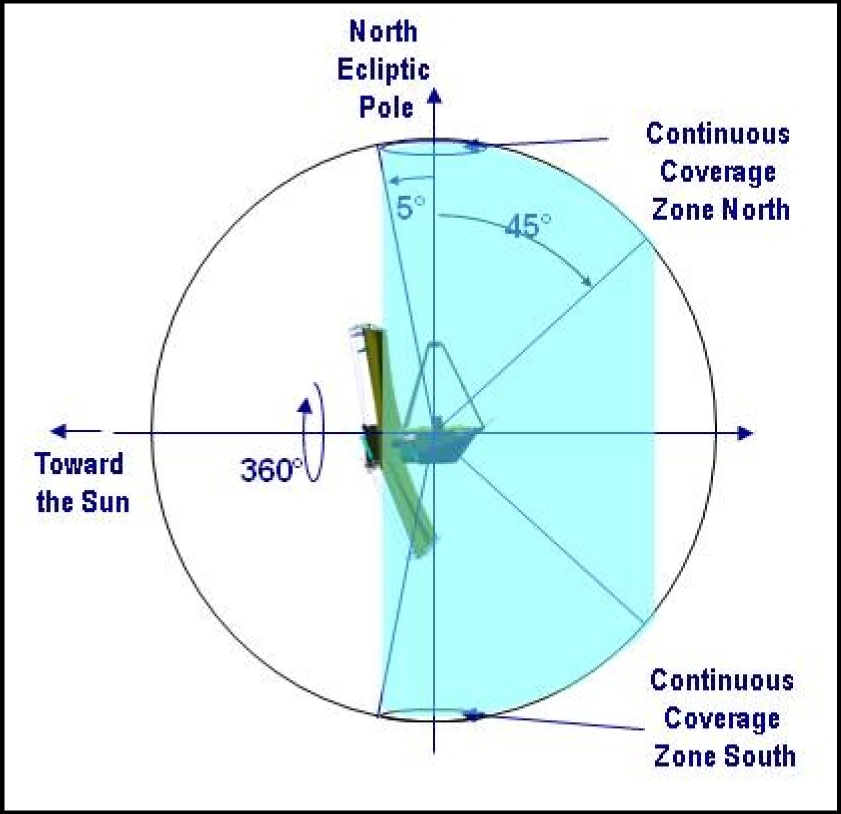
- Provide a primary mirror that is larger in diameter than available rocket fairings
- Achieve a high stability cryogenic 40K (-233 C, -388 F) operating temperature

The JWST will be placed in orbit about the Sun-Earth L2 point approximately 1.5 million km (1 million miles) from Earth

An L2 point orbit was selected for JWST to enable passive cryogenic cooling

- Unstable orbit: station-keeping thrusters required
- Propellant sized for 10 years (delta-v ~ 93 m/s)
- ~100 day direct transfer trajectory





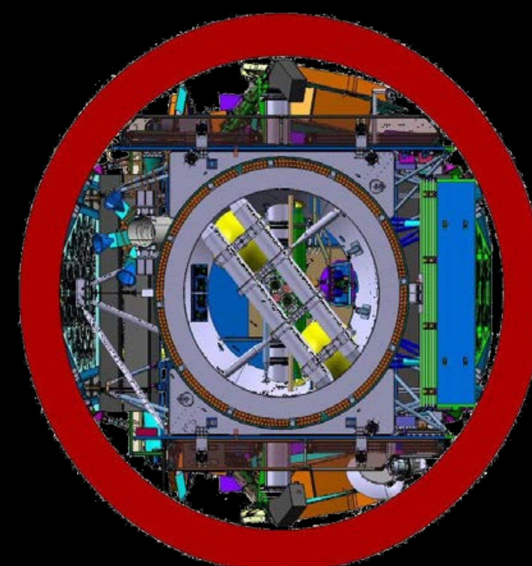
The JWST can observe the whole sky while remaining continuously in the shadow of its sunshield

- Field of Regard is an annulus covering 35% of the sky
- The whole sky is covered twice each year with small continuous viewing zones at the Ecliptic poles

The telescope requires a segmented deployable mirror

Ariane 5 ECA

- Ariane V ECA launch vehicle (5 m diameter fairing)
- Launch from Kourou Launch Center (French Guiana) with direct transfer to L2 point.
- 6530 kg payload launched at ambient temperature with on orbit cooling to 50 K via passive thermal radiators
- 40 deployable structures and 178 release devices



The JWST program is a multi-agency partnership

Launch Segment

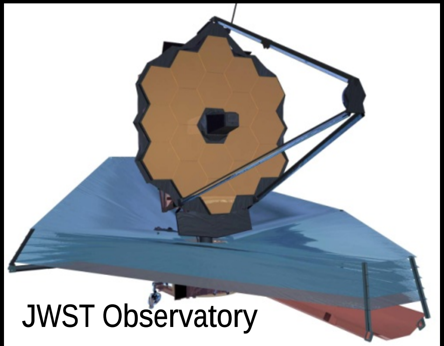
Ariane Launcher

Launch Vehicle

Payload Adapter

Launch Site Services

Observatory Segment



JWST Observatory

Optical Telescope Element (OTE)

Integrated Science Instrument Module (ISIM)

NIRCam | MIRI | NIRSpec | FGS

Spacecraft Element (SE)

Spacecraft Bus

Sunshield

Ground Segment

Deep Space Network

Space Telescope Science Institute

Science and Operations Center (SOC)

Common Systems

- Provided by NASA
- Provided by ESA
- Provided by CSA

Who was James Webb?

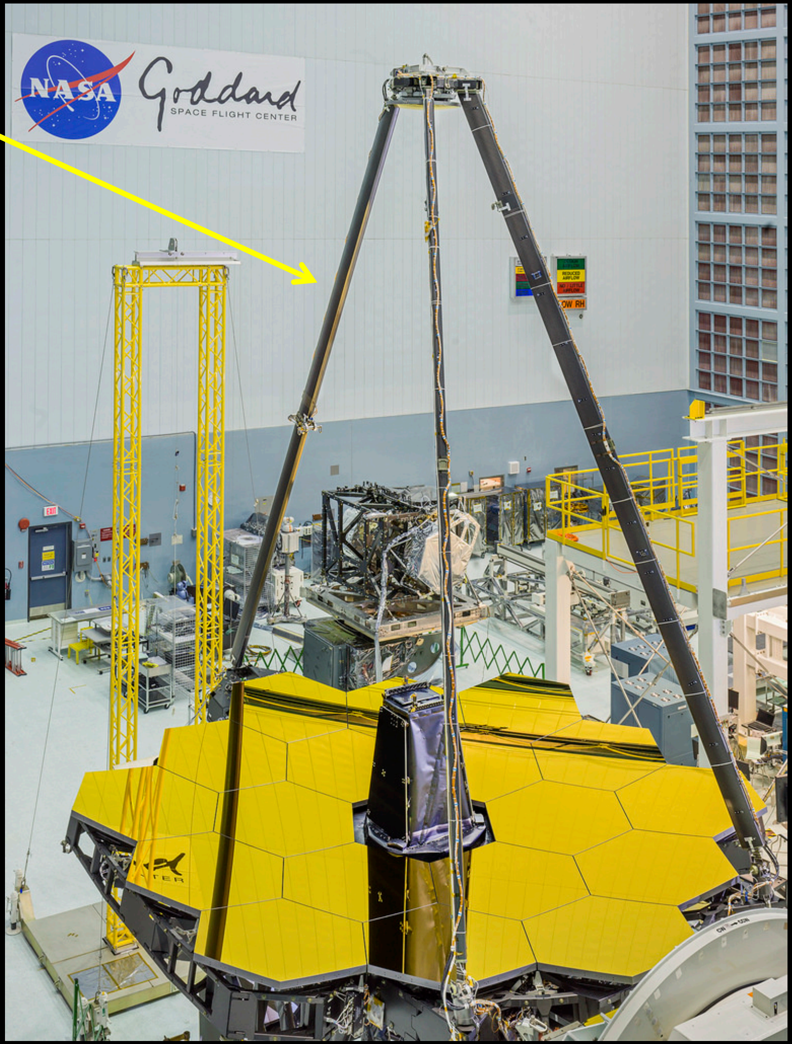
James Webb (1906 – 1992):
Second Administrator of NASA (1961 – 1968)
Oversaw:
- first manned spaceflight programs: Mercury, Gemini, Apollo
- Mariner, Pioneer planetary exploration programs

The JWST space vehicle consists of three elements

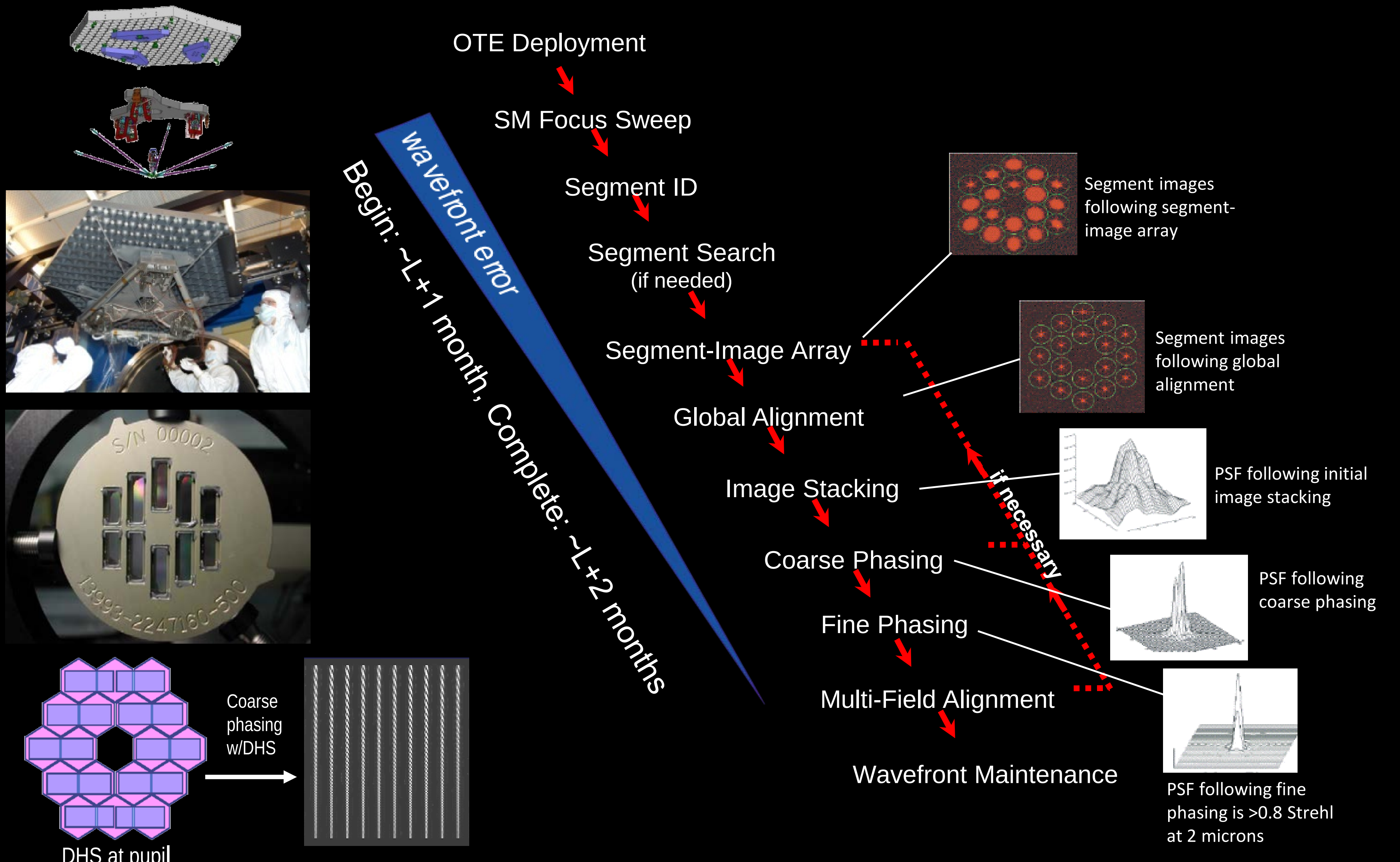
Optical Telescope Element (OTE)
Collects star light from distant objects

Integrated Science Instrument Module (ISIM)
Extracts physics information from star light

Spacecraft
Attitude control, telecom, power & other systems



The mirror segments are adjusted in tip/tilt and radius of curvature during flight, enabling them to perform together as a single large mirror.



The telescope mirrors are fabricated from Beryllium

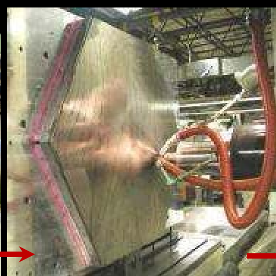
Key physical properties of Beryllium:

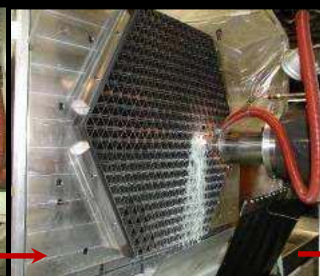
- low coefficient of thermal expansion at 50 K
- high thermal conductivity
- high stiffness to mass ratio

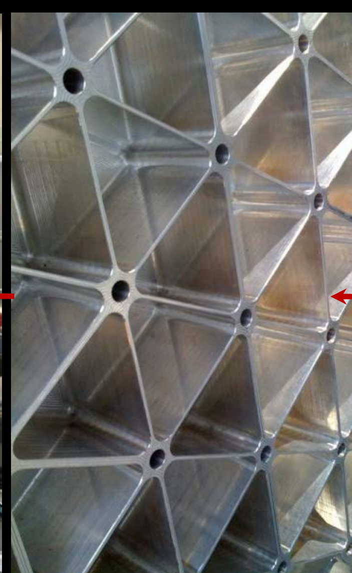
- Type O-30 spherical powder
  - uniform CTE, high packing density, low oxide content

Primary mirror mass properties

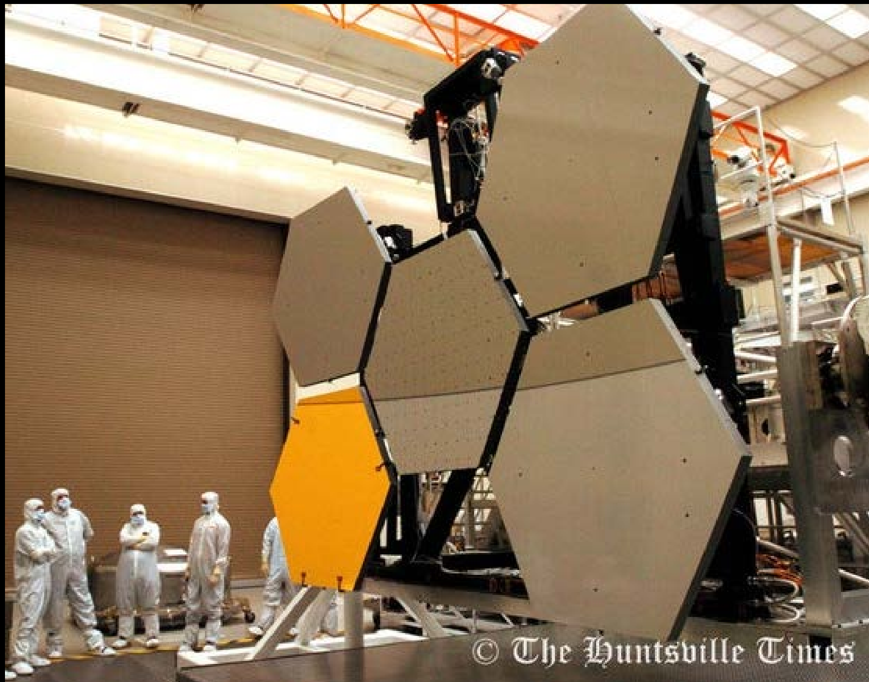
- substrate: 21.8 kg
- segment assembly: 39.4 kg
- OTE area density: ~28 kg m^{-2}
  - HST (ULE) ~ 180 kg m^{-2} (~ 6X heavier)
  - Keck (Zerodur) ~ 2000 kg m^{-2} (~71X heavier)

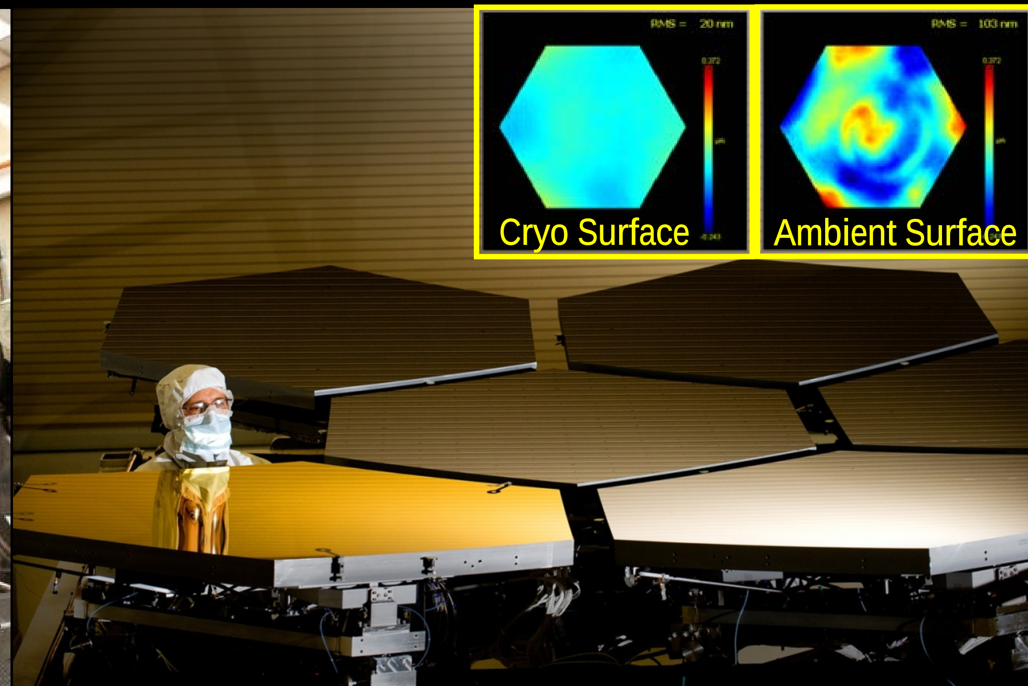


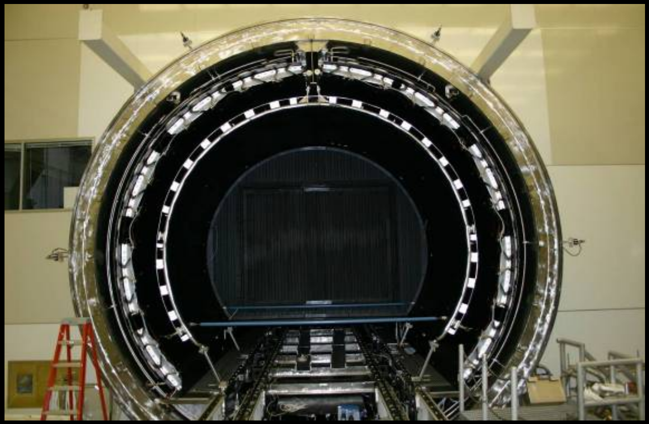




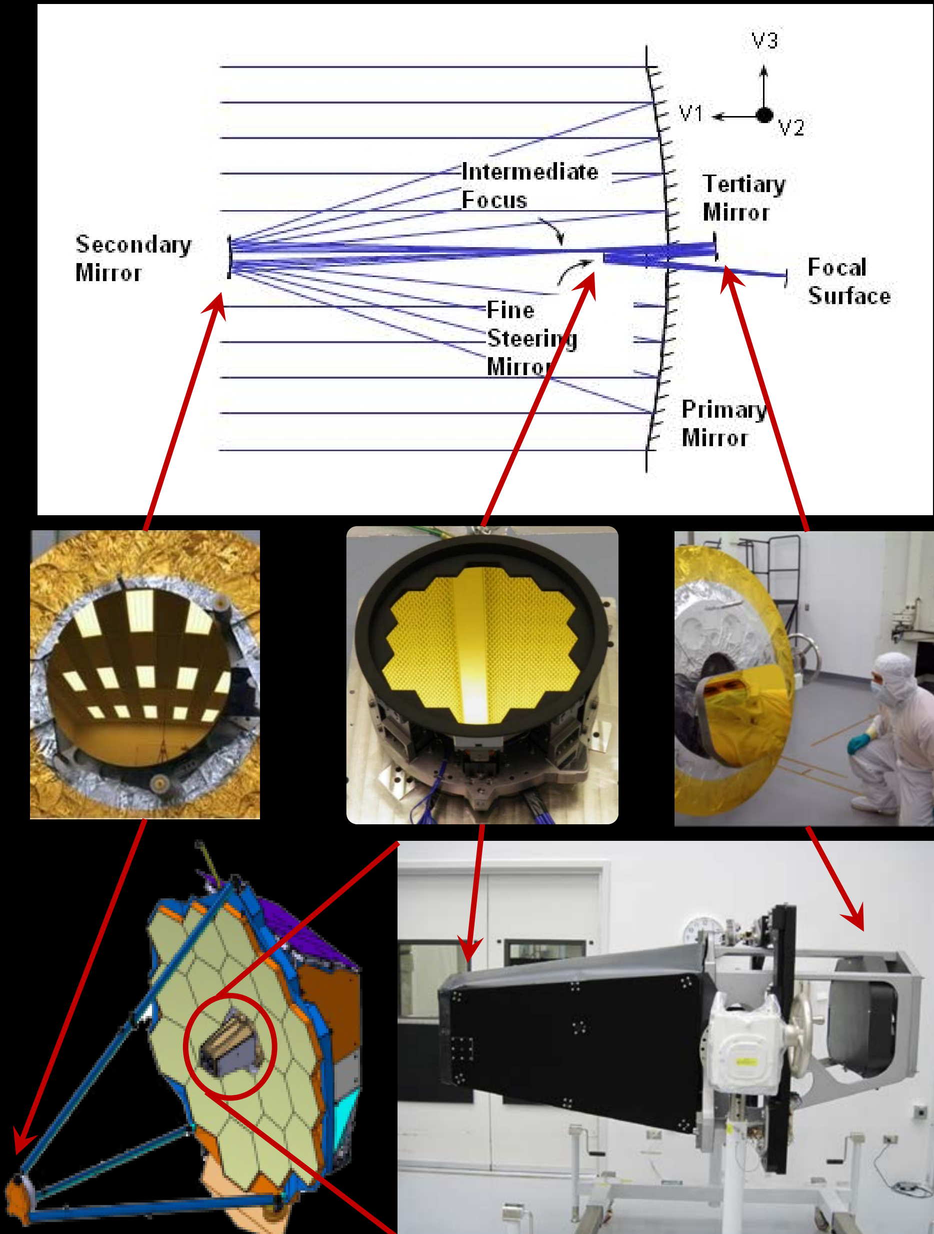
A specially instrumented space simulation chamber at Marshall Space Flight Center was used to optically test the primary mirror segments at 50 K (-225 C, -370 F)





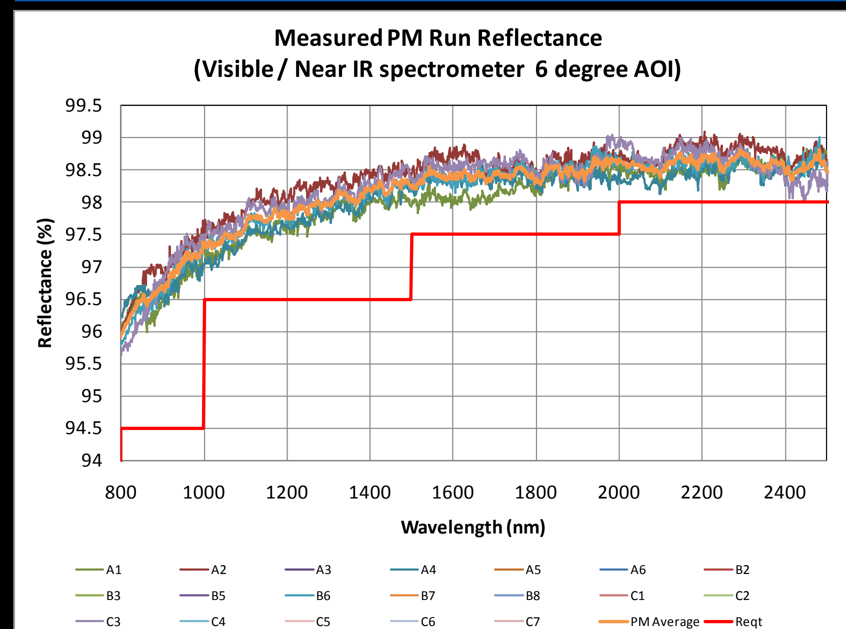


All telescope optics are in-spec in every respect



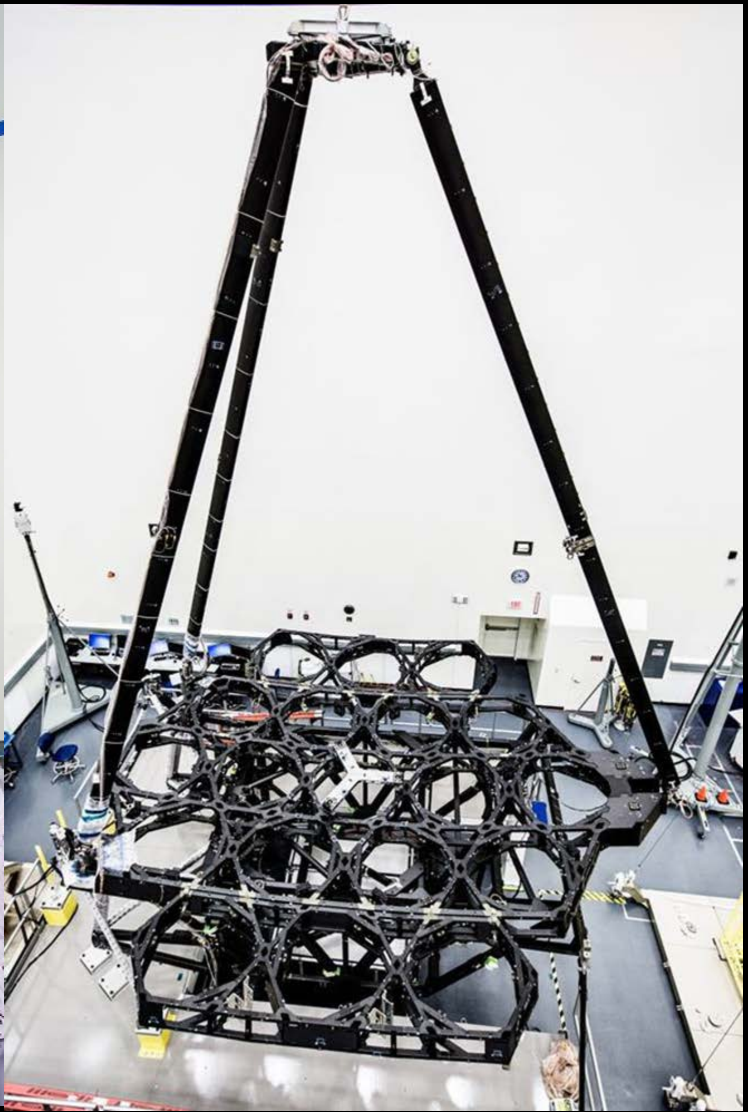
All of the mirrors are seen through testing to be smooth and reflective enough to enable the mission science objectives

Mirror	Total RMS SFE (nm)	Requirement RMS SFE (nm)
18 primary Segments (Composite Figure)	25.0	25.8
Secondary	19.8	23.5
Tertiary	20.5	23.2
FSM	14.7	18.7



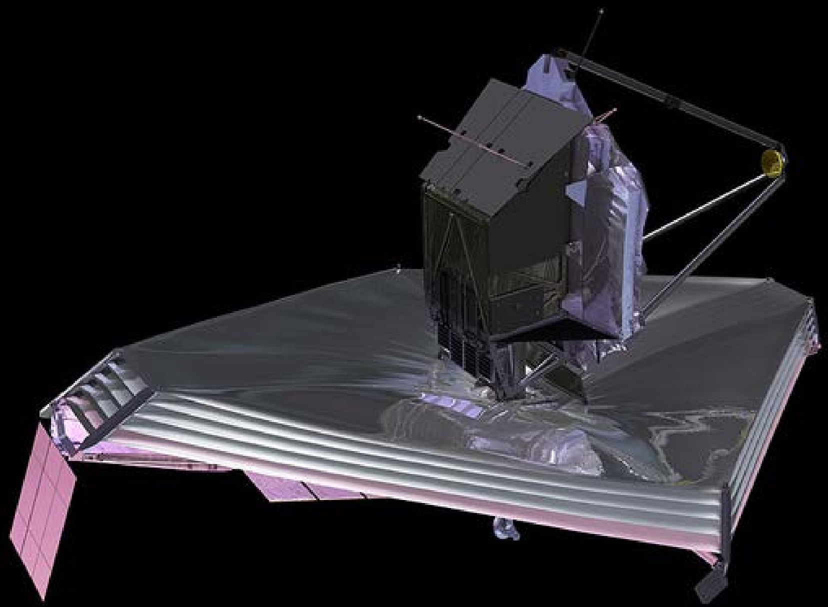
Buildup of telescope flight structure is complete

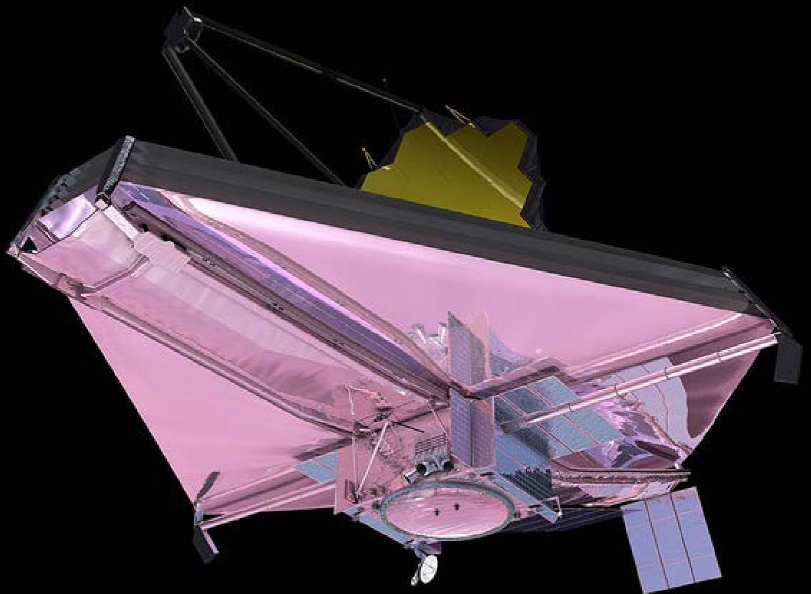
The structure consists of ~3,200 bonded composite piece parts



OTE pathfinder structure manual deployment test: June 2014

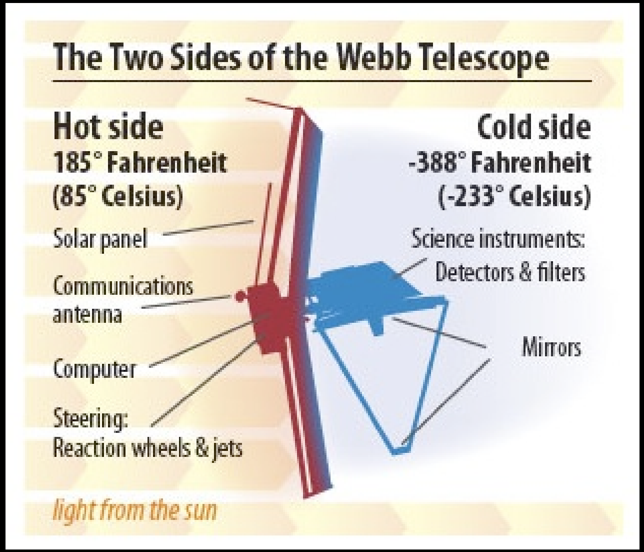
The JWST's 5 layer sunshield has an SPF of ~10^6





Sunshield Facts

- Measures 73 x 40 feet and has 5 layers
- Made of heat-resistant Kapton coated with silicon on sun side and aluminum on other surfaces
- Sun side reaches 358 K (85^o C), dark side stays at 40 K (-233^o C)
- Each of 5 layers consist of 50 pieces to form shape
- Seaming involves 7,000 inches of thermal welds
- Seam-to-seam accuracy ~ 0.05 inch with shape of (tennis court size) layers accurate to a few tenths of an inch



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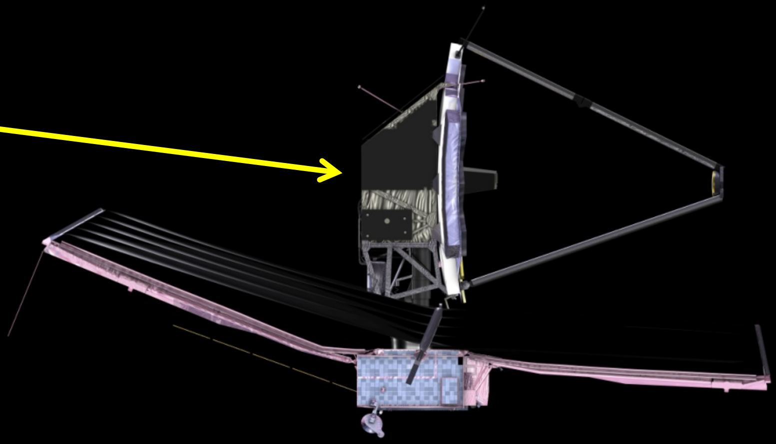
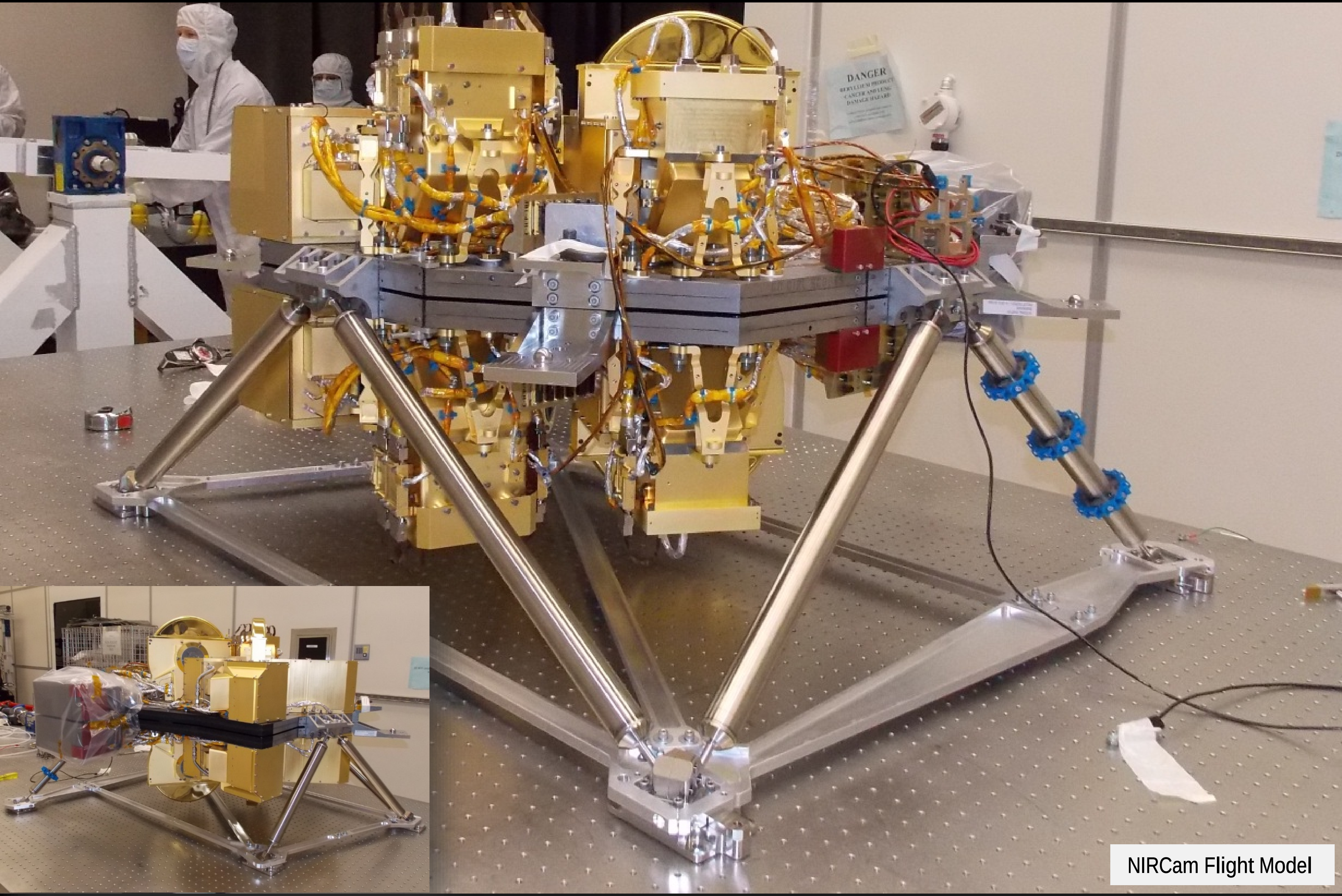
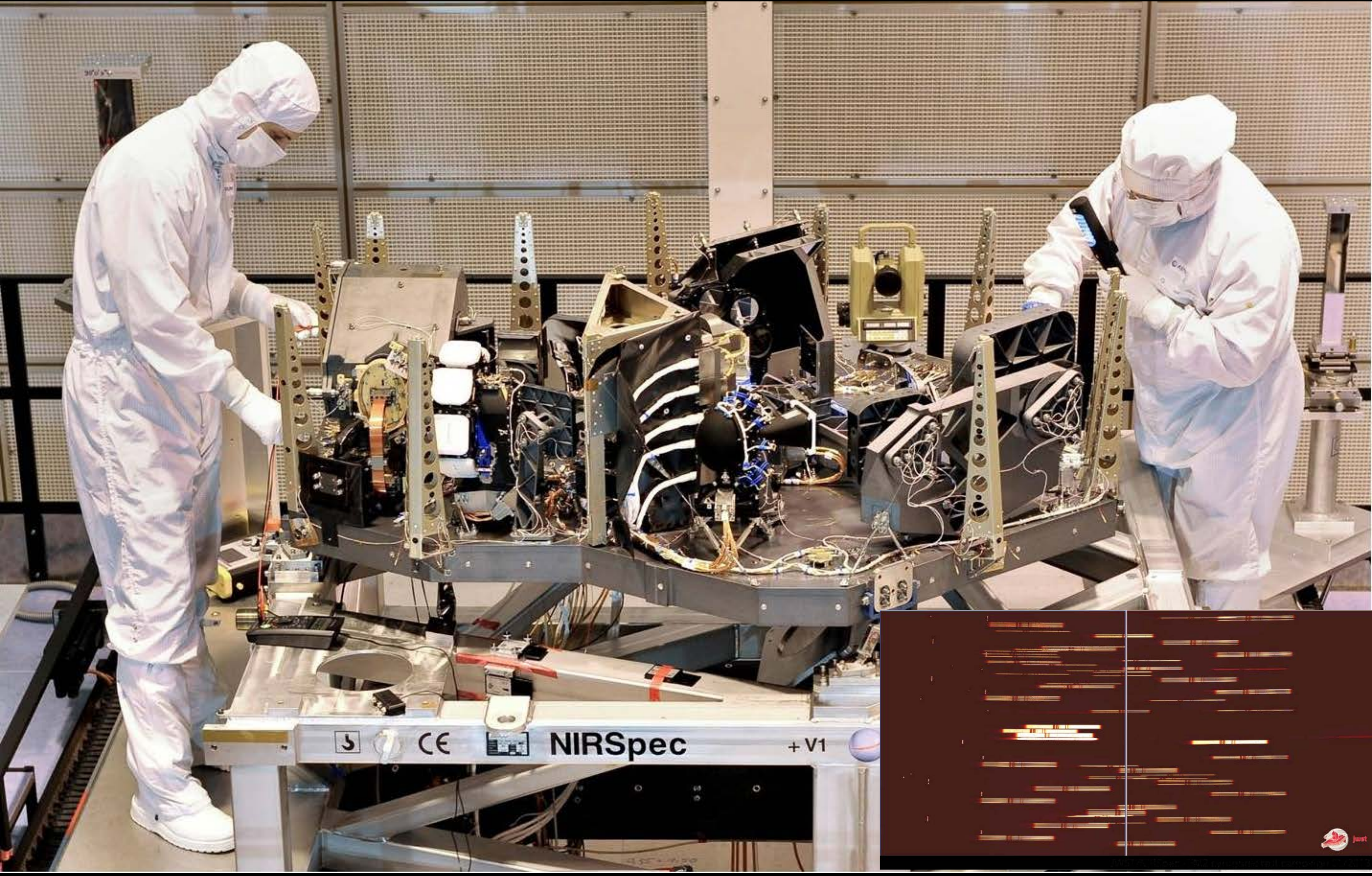
Attitude control, telecom, power & other systems



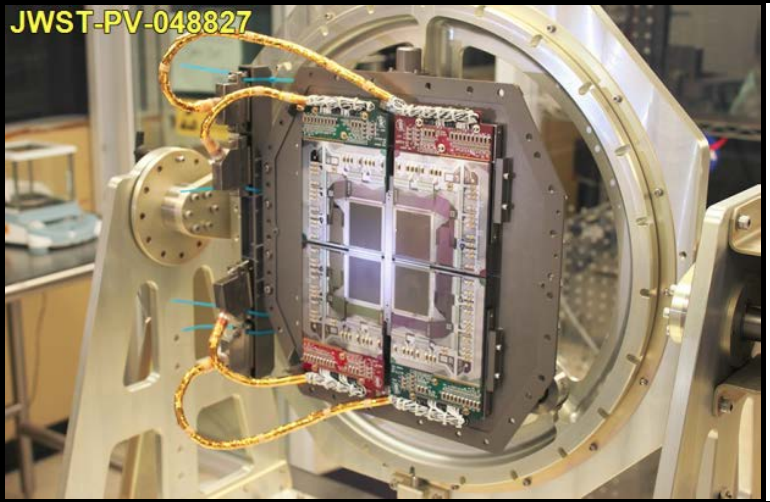
The NIRCam will image the earliest epoch of galaxy formation

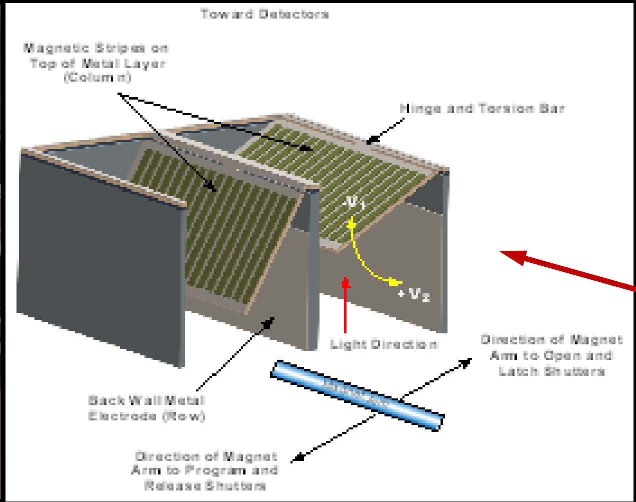


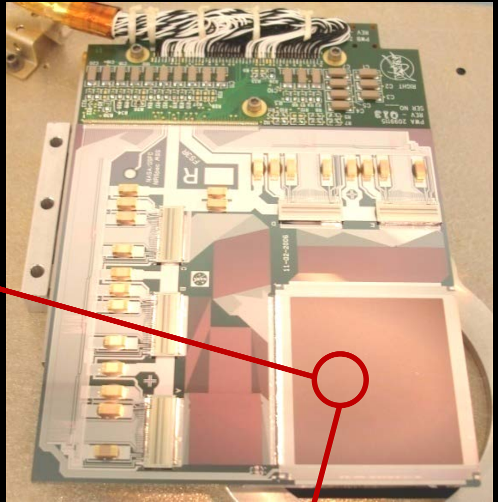
NIRSpec can obtain spectra of 100 compact galaxies simultaneously

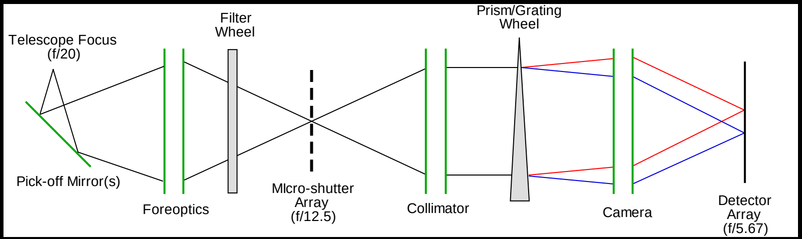


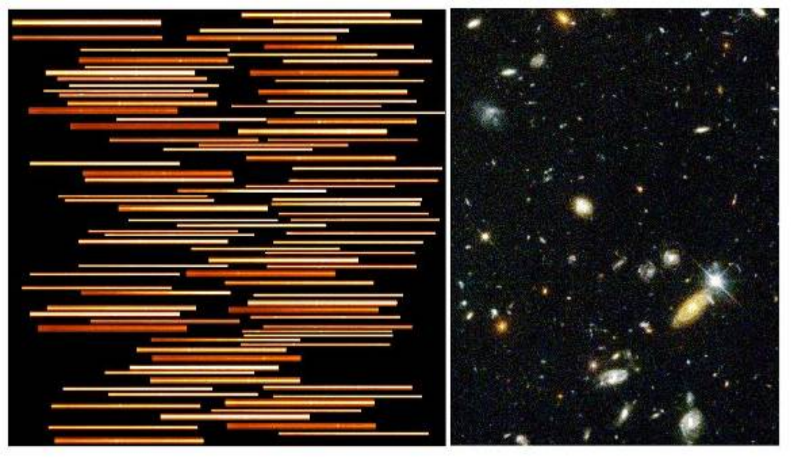
Aperture control: 250,000 programmable micro-shutters

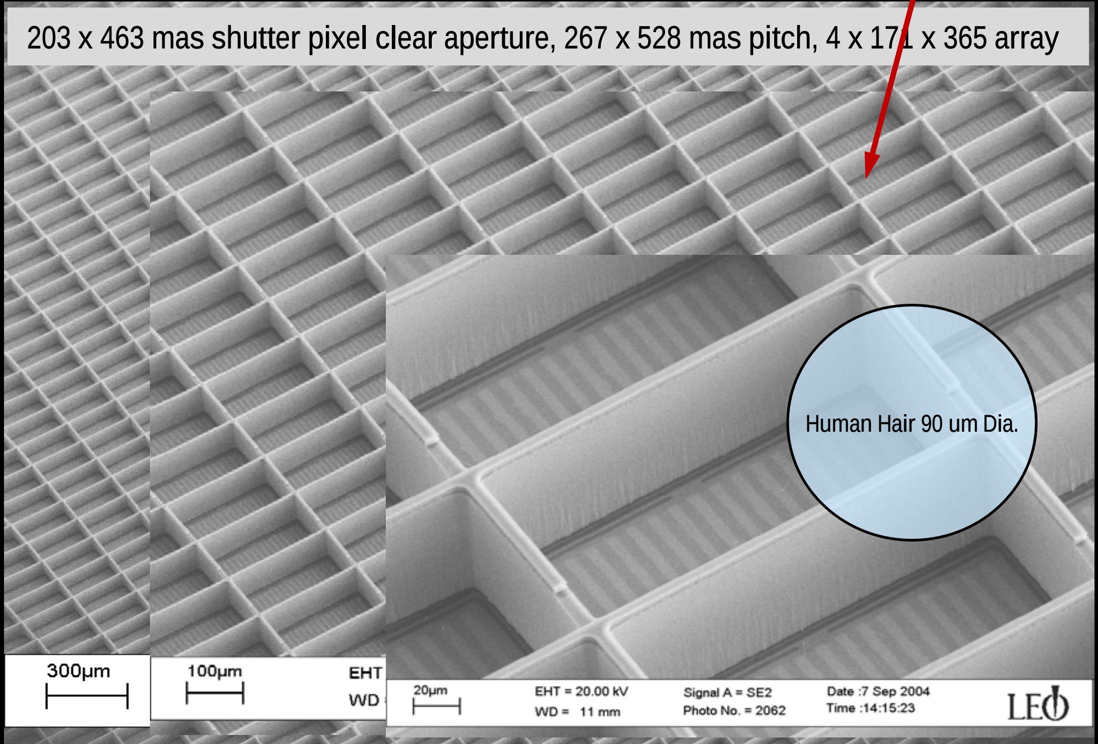










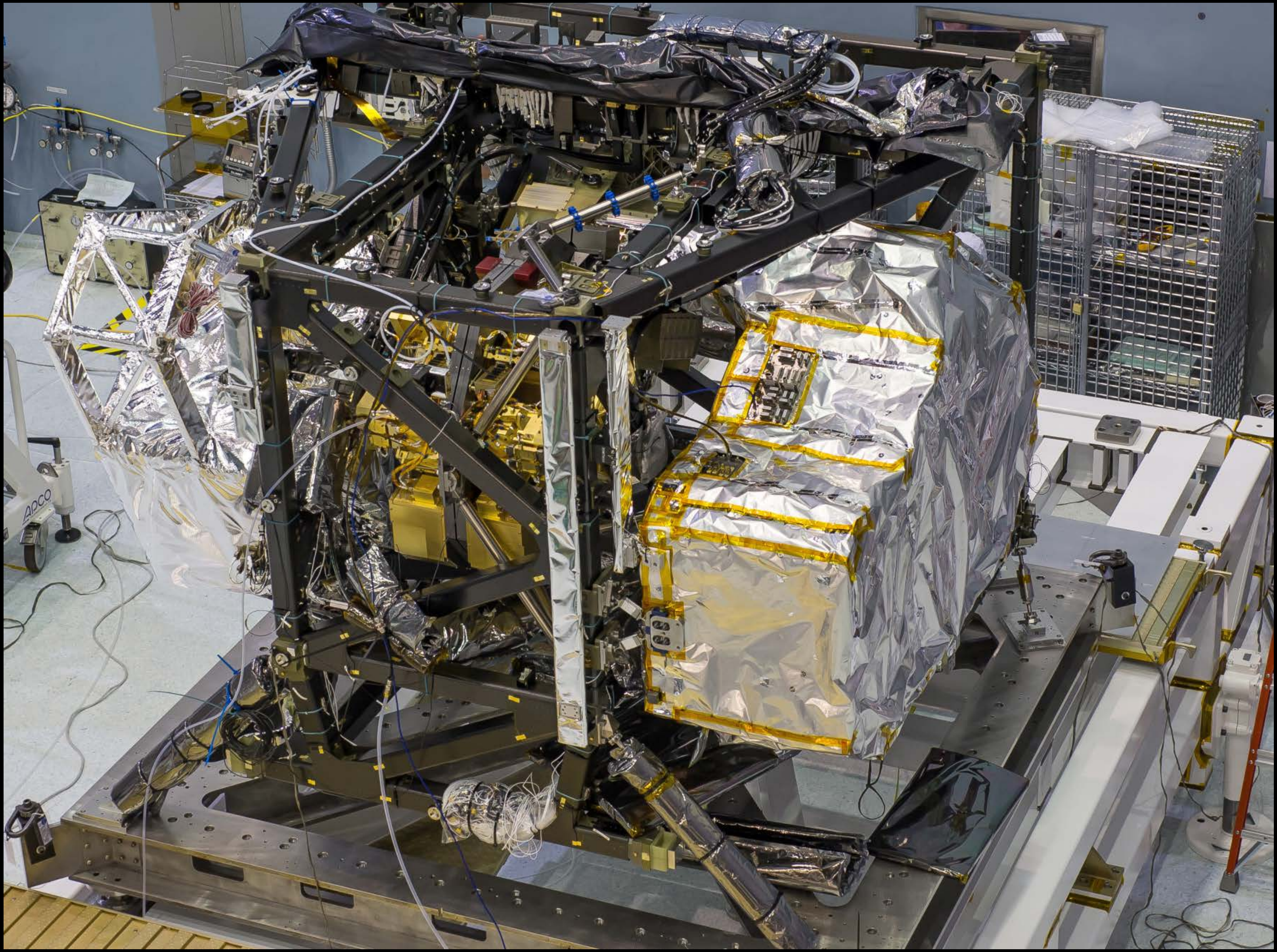


MIRI will provide humanity's first high definition view of the mid-infrared universe

MIRI flight model

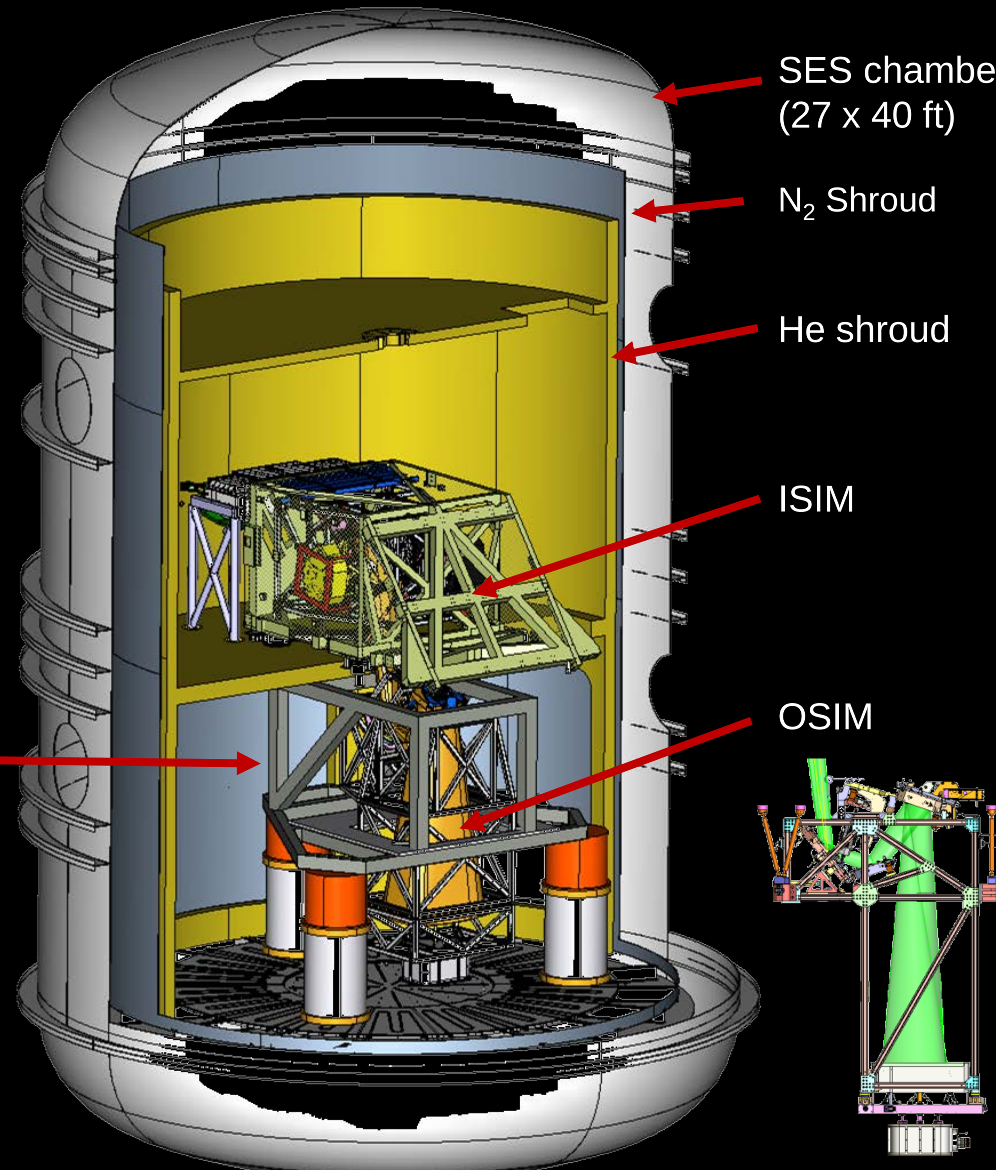
FGS can sense pointing to 1 millionth degree precision
NIRISS can image exoplanets that are too close to their star for coronagraphs

The science instrument payload (ISIM) began construction during 2006 and completed acceptance testing during March 2016



ISIM was tested in the Goddard Space Environment Simulator (SES) chamber using a cryogenic telescope simulator (OSIM)

The 3rd of 3 100 day SES test cycles of the ISIM was completed during Feb 2016



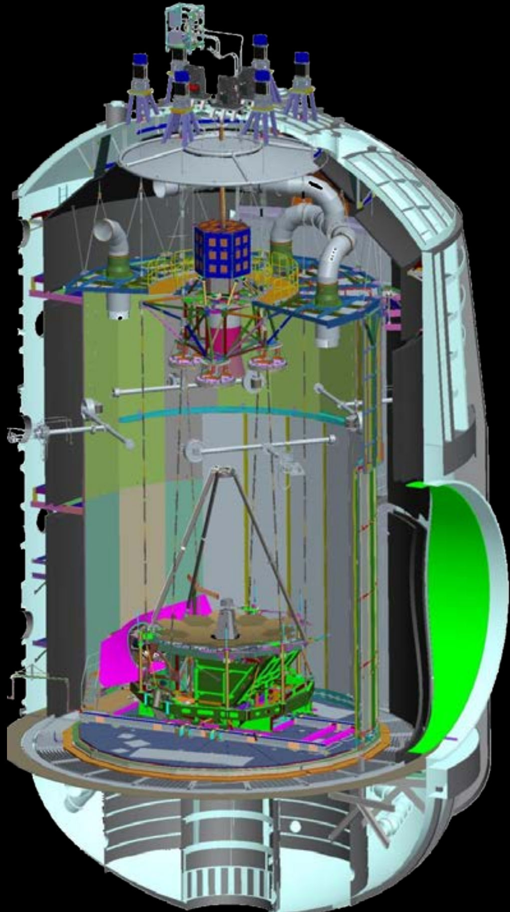
The telescope and instrument module were integrated to each other at GSFC and are now at Johnson Space Flight Center for final optical testing

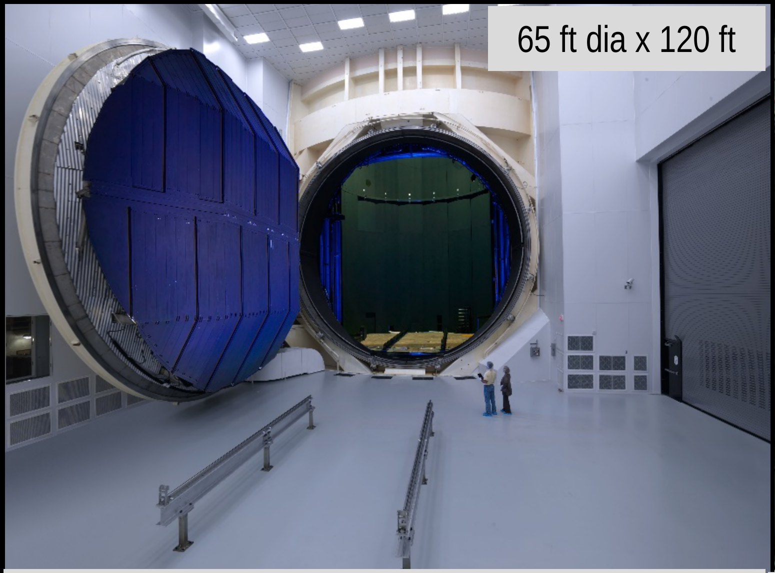
STTARS being loaded into a C5 aircraft

Space Telescope Transporter for Air Road and Sea (STTARS)

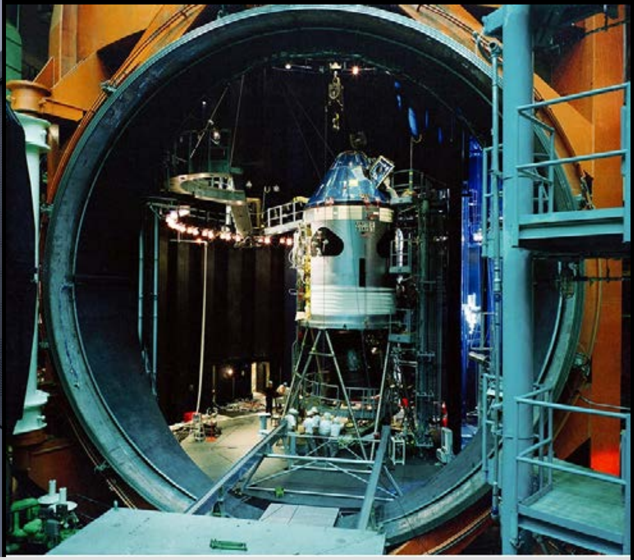
Then, during July - October 2017, the OTE + ISIM was tested in the largest space simulation chamber in the world

Apollo era facility extensively refurbished for JWST
Largest deep cryogenic space simulation chamber
Performance certification completed during Aug 2012
13 K and 10^{-8} Torr reached during test



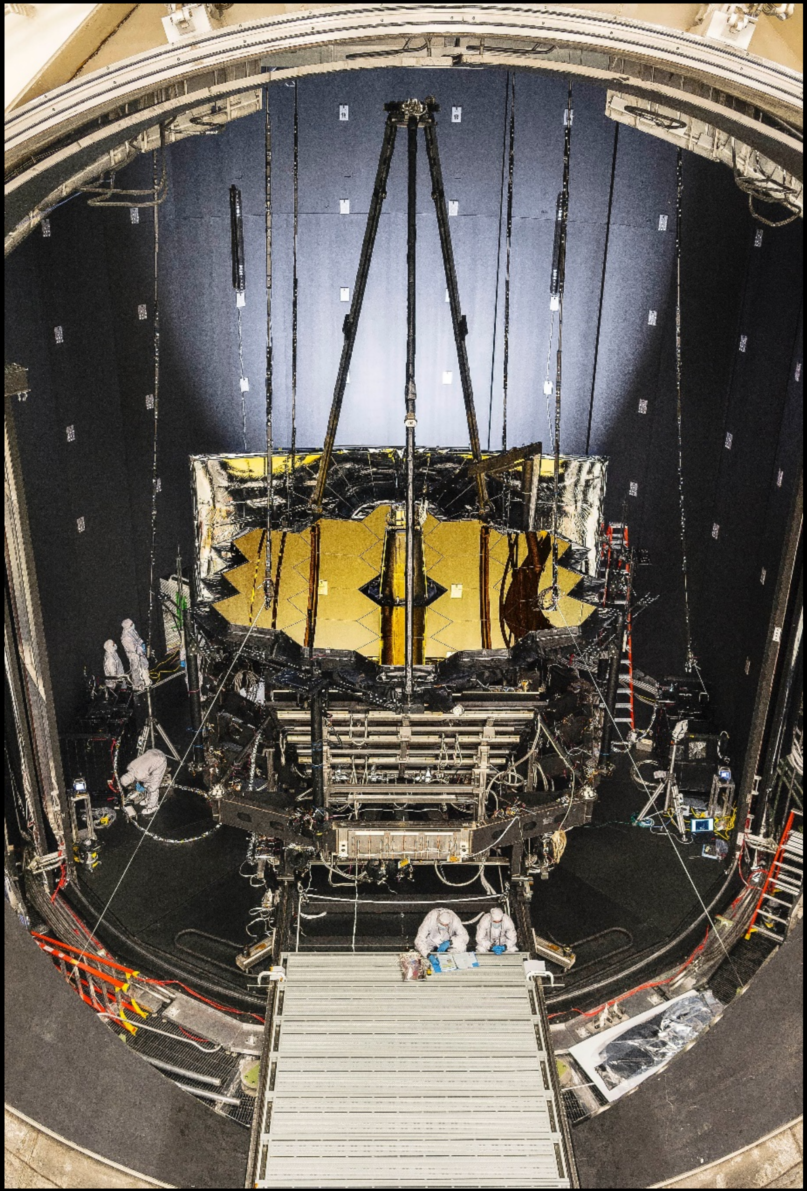


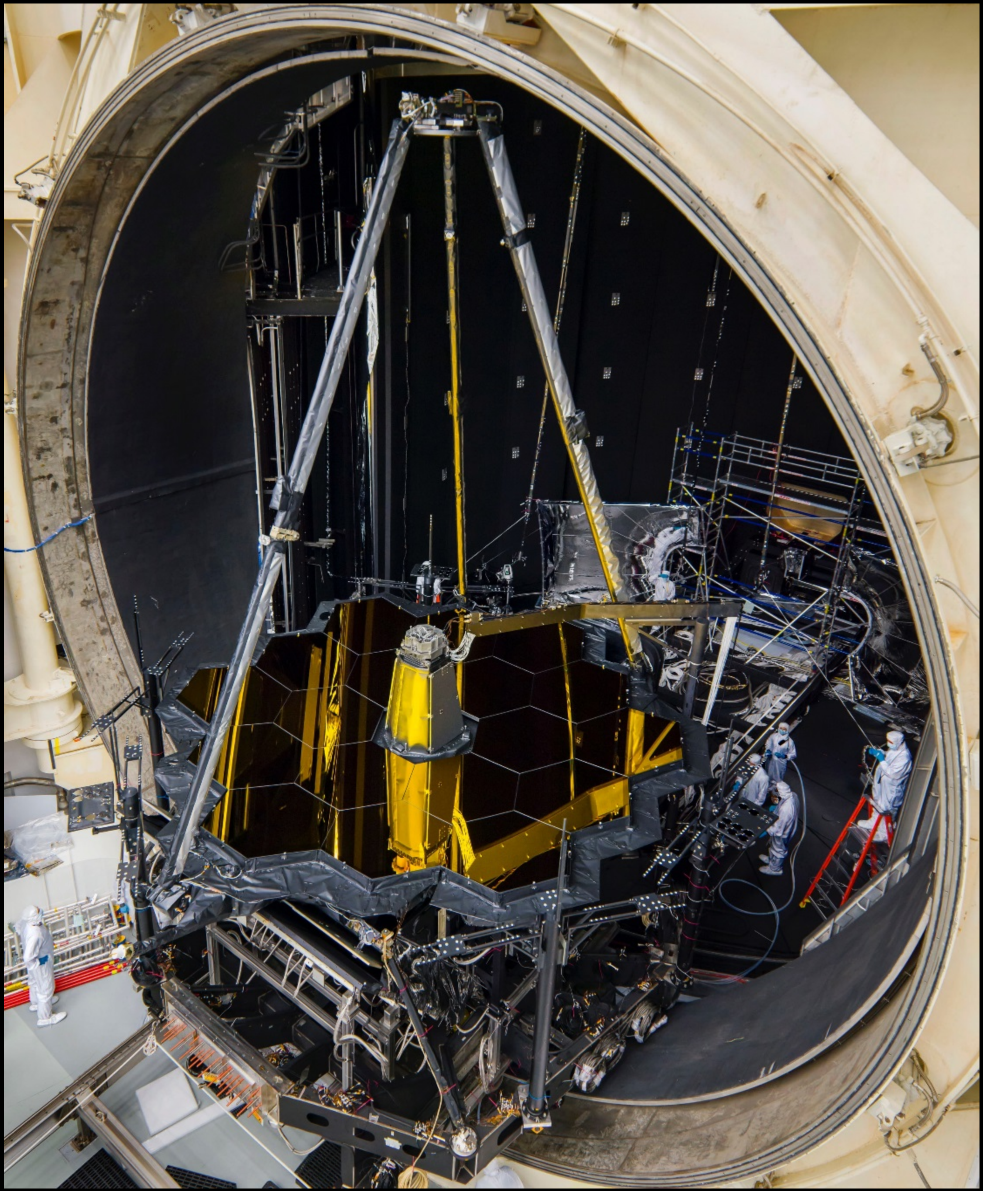
JSC Chamber A today



JSC Chamber A during Apollo

End-to-end optical testing began at JSC during July 2017.

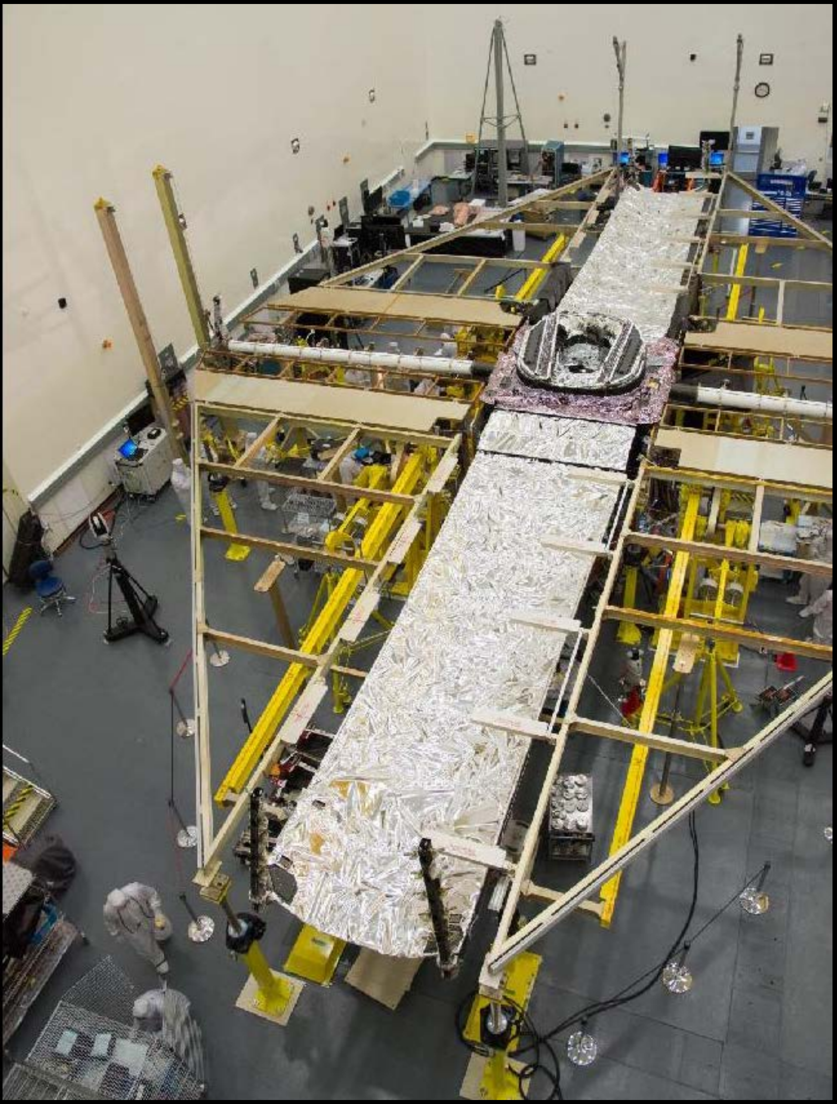




The telescope and instrument module will then be sent to Northrop Grumman Aerospace Systems for integration with the spacecraft bus and sunshield during Autumn 2017

Space Telescope Transporter for Air Road and Sea (STTARS)

Spacecraft & Sunshield I&T is nearing readiness to be integrated with the telescope during Autumn of this year



Then … The JWST will be transported by ship through the Panama Canal to French Guiana for launch during 2018

6900 Nautical Miles
Approximately 20 days

Roll on roll off transport ship built in the Netherlands by Merwede Shipyards
Length 116m
Displacement about 4200 metric tons
Garage deck length 95m (plenty of room for STTARS)
Speed: 15 knots

Space Telescope Transporter for Air Road and Sea (STTARS)

Standing on his shoulders, future Einsteins are asking big questions

- What happened before the Big Bang?
- What's at the center of a black hole?
- What is our cosmic destiny?
- What are space and time?
- Are we alone?

... Big Questions, Ripe to Answer

YOU can join the quest for answers


JWST Astronomer
Dr Jane Rigby


JWST Astronomer
Dr Jason Kalirai


JWST Astronomer
Dr Amber Straughn


JWST Engineer
Robert Rashford


JWST Astronomer
Dr Jon Gardner


JWST Manager
Dr Kalyani Sukhatme


JWST Manager
John Durning

The scientists, engineers, and managers that use and build space observatory's come from all walks of life.

You can join them!

Go to college. Study science, engineering, and math

The book of nature lies continuously open before our eyes (I speak of the Universe) but it can't be understood without first learning to understand the language and characters in which it is written. It is written in mathematical language, and its characters are geometrical figures. - Galileo Galilei -- As true today as it was 400 years ago!

The End (of this presentation)

But

with JWST, we will see the beginning of *everything*

The first galaxies
The origins of galactic structure
The birth of stars
The creation of planets
and more …

You can follow the action: @NASAWebb #JWST